Water Distribution Network Design for SRM University using EPANET

R. Sathyanathan[1*], Mozammil Hasan[2], V.T. Deeptha[3]

[1]Assistant Professor (S.G), Department of Civil Engineering,
SRM University, Kattankulathur, Chennai

[2]B.Tech., Student, Department of Civil Engineering,
SRM University, Kattankulathur, Chennai

[3]Environmental Consultant,
Chennai, Tamil Nadu, India

[*]*Corresponding author's email: sathyanathan.r [AT] ktr.srmuniv.ac.in*

ABSTRACT—*The main objective was to study and design the water distribution system requirements using EPANET, so that water is supplied equitably to the consumers with sufficient pressure head at the desired locations in SRM University.The materials used for this study includeSRM campus plan, water distribution parameters such as block wise population, and water demand, distribution network parameters such as elevations, pipe length and EPANET software. The water demand was obtained after considering the population of each block. The nodal elevations were measured using Height and Instrument method of levelling.Digitization of streets and buildings in SRM campus was done in Google Earth and it was further used as backdrop in EPANET to carry out the hydraulic simulation.The water distribution network of SRM campus consists of 29 pipes of uniform material, 32 junctions, 5 pumps and a source reservoir from which water is pumped and later distributed to the entire network. The pipes used in the network system are of uniform diameter of 250 mm. The cast iron pipes having roughness coefficient of 85 are used throughout the network system. The total length of the pipes in the network is 2422 m. The water demand during the peak hour is around310 m^3/hr, while the demand during the non- peak hour is around 83 m^3/hr. Thus the overall water demand for a day is about 3354 m^3, although the supplied quantity of water is about 4950 m^3. Hence there is no overall shortage of water throughout the day. Moreover the excess water generated during the non- peak hours can be stored in the sump and later used during peak hours. The demand during the peak hours is 3.75 times the demand during the non- peak hours. There is also a decrease in pressure head occurring at the peak hour as compared to the non- peak hours with an overall reduction of 26% throughout the nodes. The main problem encountered in this water distribution network is the presence of dead ends which inturn leads to stagnation of water in pipes and thereby reducing the pressure and velocity at these ends. Although this constraint can be removed by looping the pipes in the network, the site conditions are not conducive for looping, as the area near the dead ends when looped goes out of the campus limits.*

Keywords—Water distribution network, EPANET, Hydraulic Modelling and Simulation

---

1. INTRODUCTION

The purpose of the study is to assess the performance of the water distribution system at SRM University campus, Kattankulathurusing EPANET software to control the variability of water delivered to the consumers. The study also aims to design a 24x7 water distribution system using EPANET for the entire campus. A water distribution system is a hydraulic infrastructure that conveys water from the source to the consumers. The system consists of elements such as junctions, pipes, tanks, reservoirs and pumps [1]. Themost important consideration in designing a water distribution system is satisfying consumer demands under a range of quantity and quality considerations during the entire lifetime for the expected demand conditions. A common purpose of a water distribution network is to deliver water to consumers based on demand quantities and desired pressures [2]. In order to fulfil the water demand of the continuously growing student's population we need to provide sufficient and uniform quantity of water through the designed network of pipes. Thus it is necessary to plan and construct a suitable water distribution network system. The simulation of the water distribution network system is done through modelling, analysis, and performance evaluation through various scenario investigations by manipulating the physical and hydraulic parameters.The simulation capabilities of EPANET have been widely utilised in the design, operations and improvement of various water network distribution systems [3]. EPANET is a computer program that performs extended period simulation of hydraulic and water quality behaviour within pressurized pipe networks. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. The hydraulic analysis and simulation of water distribution system are prior steps that need to be accomplished before conducting water quality simulation[4].

1.1 Study Area

The project site is SRM University campus situated at Kattankulathur, Chennai. The SRM University (Kattankulathur) is 40 km from Chennai city on NH 45, and around 20 km from Chennai Airport. The campus is spread across 250 acres of land with ample greenery. This campus has a network of 30 blocks for academic and administrative activities with a built up area of over 150000 m^2.

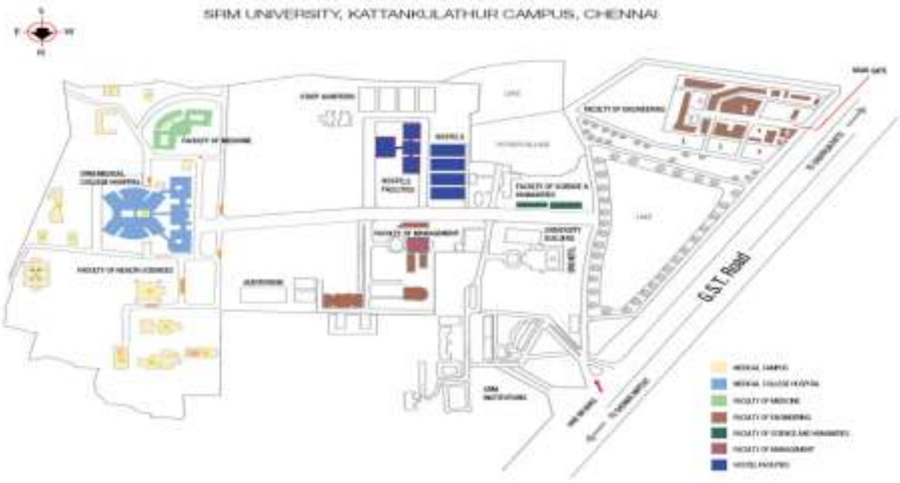

Figure 1:SRM University, Kattankulathur campus plan

2.METHODOLOGY

2.1 Materials

The materials used include SRM campus plan, water distribution parameters such as block wise population, and water demand, distribution network parameters such as node elevations, and pipe length and EPANET software.

2.2 Levelling Work

Reduced levels (R.L) were calculated by the Height of Instrument method. Using these reduced levels the elevation at each node was determined.The spot heights of the distribution nodal points were carried out relative to the bench mark by dumpy level.

2.3 Block wise Population Data and Water Demand Calculation

The block wise population data was collected and the water demand for each building was arrived based onIS code 1172:1993. The water consumption for each building in terms of litres per head per day is as follows[5]:

- Hostel - 135 l/h/d
- College - 45 l/h/d
- Office - 45 l/h/d
- Auditorium - 15 l/h/d
- Hospital - 450 l/h/d

The product of population of each block with that of per capita demand gives the water demand for that respective building.Thewater demand calculated for each building was specified in the nodes which were located in front of the respective buildings as shown in Table 2.1.

Table 2.1: Water demand for each building

Building	Water Demand (CMH)
University building	28.81
Hotel management block	05.63
Meenakshi hostel	01.69
Paari block	05.35
Kaari block	05.26
Oori block	05.31
Adhiyaman block	05.47
NRI block	03.02
Agasthiyar block	00.81
Sannasi block	02.95
Began hostel	01.23
Malligai	03.07
Thamarai	03.09
Mullai	03.04
Monranjitham	03.90
Kurunji	01.52
Senbagam	02.79
Staff Quarter A	01.45
Staff Quarter B	02.03
Chemistry lab	00.90
Biotech block	06.75
Architecture block	04.50
MBA block	06.75
Tech park	25.21
Auditorium	02.50
Dental block	04.05
Medical collage	01.50
SRM hospital	05.63
Basic engineering block	09.00
PF hostel	05.49

*CMH- cubic metres per hour

2.4 SRM Campus Digitization in Google Earth

The digitization of streets and buildings in SRM campus was done in Google Earth and it was further used as a backdrop in EPANET to carry out the hydraulic simulation as shown in Figure 2.

Figure 2: Digitization of SRM campus in google earth

2.5Hydraulic Modelling and Simulation

The shape files of the facilities, pipeline drawings and system boundaries for the entire campus isopened in QGIS 2.8.7. The *.shp file is converted to bitmap image (.bmp) file. Finally this .bmp file is used as a backdrop in EPANET software.This allows us to assign prefixes to the junctions and pipes and obtain a working model of the system in EPANET. Now the pipe network layout and distribution is drawn. The junctions are created in front of each building with their respective base demand. These junctions are joined together with pipes of varying length. The length of the pipe lines between the nodes are arrived from Google earth and incorporated in EPANET. The pumps are also used in the network system to meet the required water demand with sufficient pressure head.

After a working model of the system is generated in EPANET, the next step is to assign water demand and elevation to the different nodes along with pipe characteristics such as pipe length, pipe diameter and roughness coefficients to the respective pipes. The process of modelling a network using EPANET involves input of the parameters or variables that most closely describe the operation of the actual system. These parameters include the shape of the tank and the pump curve which describes the operation of the pump. The hydraulic simulation is done for a period of 24 hours with time step of 3 hours each. The peak water demand occurs twice a day, from 6–9am and 6–9pm,and is particularly pronounced in the college hostels.

Following are the steps carried out to model water distribution network using EPANET [6].

a) Draw a network representation of distribution system or import a basic description ofthe network.
b) Edit the properties of the objects that make up the system. It includes editing the properties and entering required data in various objects like reservoir, pipes, nodes and junctions.
c) Describe how the system is operated.
d) Select a set of analysis option.
e) Run a hydraulic/water quality analysis.
f) View the results of the analysis.

3. FINDINGS/ RESULTS

During the simulation, changes in selected parameters such as flow, velocity, head and water pressure at various nodes at each hour were observed. The water distribution network of SRM campus consists of 29 pipes of uniform material, 32 junctions, 5 pumps and 1 source reservoir from which water is pumped and later distributed to the entire network. The pipes used in the network systemare of uniform diameter of 250mm. The cast iron pipes having roughness coefficient of 85 are used throughout the network system.

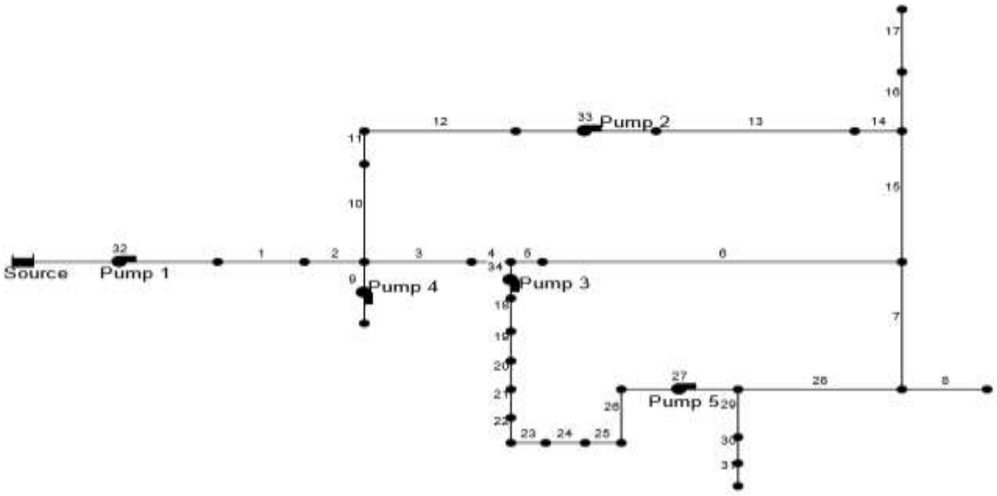

Figure 3: SRM campus water distribution network

The water demand during the peak hours is 310 m^3/hr, while the demand during the non-peak hours is 83 m^3/hr. Thus the total water demand for one day is 3354 m^3, whereas the supplied quantity of water is about 4950 m^3. Hence there is no overall shortage of water throughout the day. Moreover the excess water can be stored in the sump and later used during peak hours wherever necessary. The demand during the peak hours is 3.75 times the demand during the non- peak hours. Further the simulation results shows that the supply as well as the demand during the 9th hour i.e. at 9 am is exactly the same. The major variation in demand takes place at the nodes that lie in front of the University building and the Tech Park. This is attributed to the large student population in these 15 storey buildings. There is also a decrease in pressure head occurring at the peak hour as compared to the non-peak hours with an overall reduction of 26% throughout the nodes.

3.1 Junction Report

Junctions are points in the network where links join together and where water enters or leaves the network.The basic input data required for junctions are elevation above a reference elevation and water demand. The output results computed for junctions are hydraulic head and pressure [4].

The junction report for the 7th hour of simulation, which is part of the peak water demand hour, i.e.6–9am, is shown in Table 3.1.

Table 3.1: Network Table – Nodes Result at 7:00 Hrs

Node ID	Elevation (m)	Base Demand (CMH)	Demand (CMH)	Pressure (m)
Junc 2	10	0	0	15.54
Junc 3	9.86	34.52	51.78	13.48
Junc 4	9.844	34.52	51.78	12.11
Junc 5	9.818	9.08	13.62	12.13
Junc 6	9.8	9.08	13.62	12.15
Junc 7	9.796	1.25	1.88	12.73
Junc 8	9.793	5.68	8.52	19.43
Junc 9	9.781	5.68	8.52	20.6
Junc 10	9.777	1.6	2.4	20.6
Junc 11	9.836	1.7	2.55	18.78

Junc 12	9.85	0.91	1.37	10.71
Junc 13	9.857	0.91	1.37	10.21
Junc 14	9.852	6.81	10.22	9.02
Junc 15	9.809	25.21	37.81	21.7
Junc 16	9.846	2.5	3.75	20.6
Junc 17	9.822	2.5	3.75	20.2
Junc 18	9.798	4.09	6.13	20.22
Junc 19	9.78	5.45	8.18	20.23
Junc 20	9.812	5.45	8.18	20.16
Junc 21	9.81	5.22	7.83	19.53
Junc 22	9.812	8.29	12.44	18.94
Junc 23	9.822	5.45	8.18	18.47
Junc 24	9.84	3.07	4.61	18.02
Junc 25	9.847	1.6	2.4	17.66
Junc 26	9.814	2.84	4.26	17.34
Junc 27	9.808	3.97	5.95	17.02
Junc 28	9.801	3.07	4.61	16.65
Junc 29	9.787	3.07	4.61	15.97
Junc 30	9.832	3.07	4.61	21.72
Junc 31	9.812	3.52	5.28	21.73
Junc 32	9.805	3.07	4.61	21.74
Junc 33	9.827	3.07	4.61	21.71
Resvr 1	5	#N/A	-309.38	0

The highest pressure achieved during simulation process is 21.74 m. 37.5% of the total nodes have pressure greater than 20 m and 87.5% of the total nodes have pressure greater than 12 m. This clearly shows that most of the nodes are having the minimum pressure head of more than 12 m except for 4 nodes falling near dead ends.

3.2 Pipe Report

Pipes are links that convey water from one point in the network to another. EPANET assumes that all pipes are full at all times. The flow direction is from the end of higher hydraulic head (internal energy per weight of water) to lower head.The principal hydraulic input parameters for pipes are diameter, length and roughness coefficient. The output results computed for the pipes are flow rates, velocity and head loss[4].

The pipe report for the 19thhour of simulation which also comes under the peak demand hour, i.e.6–9 pm is shown in Table 3.2.

Table 3.2: Network Table – Links Result at 19:00 Hrs

Link ID	**Length (m)**	**Flow (CMH)**	**Velocity (m/s)**	**Unit Headloss (m/km)**
Pipe 1	85	309.38	1.75	25.91
Pipe 2	75	257.6	1.46	18.46
Pipe 3	70	7.14	0.04	0.02
Pipe 4	45	-6.48	0.04	0.02

Pipe 5	30	-263.88	1.49	19.3
Pipe 6	342	-265.75	1.5	19.55
Pipe 7	170	-150.71	0.85	6.84
Pipe 8	126	2.4	0.01	0
Pipe 10	125	196.13	1.11	11.14
Pipe 11	45	194.76	1.1	11
Pipe 12	110	193.4	1.09	10.85
Pipe 13	165	145.37	0.82	6.4
Pipe 14	70	141.62	0.8	6.1
Pipe 15	170	123.56	0.7	4.73
Pipe 16	70	14.31	0.08	0.09
Pipe 17	84	8.18	0.05	0.03
Pipe 18	40	235.6	1.33	15.65
Pipe 19	40	227.77	1.29	14.7
Pipe 20	35	215.33	1.22	13.24
Pipe 21	35	207.16	1.17	12.33
Pipe 22	30	202.55	1.15	11.83
Pipe 23	30	200.15	1.13	11.57
Pipe 24	30	195.89	1.11	11.12
Pipe 25	35	189.94	1.07	10.5
Pipe 26	70	185.33	1.05	10.03
Pipe 28	150	161.63	0.91	7.79
Pipe 29	65	14.49	0.08	0.09
Pipe 30	35	9.21	0.05	0.04
Pipe 31	45	4.61	0.03	0.01

The points showing negative demands are actually points where the supply enters into the water distribution networks. By convention, a negative (-) draw-off at a node signifies supply going into the network, while a positive (+) draw-off signifies supply going out of the network [7]. The distribution of velocity during the peak water demand hour shows that 16 links have a velocity greater than 1 m/s, while 8 links have a velocity less than 0.6 m/s. A few nodes have less than 0.05 m/s velocity, which may be due to the presence of dead ends.

3.3 Current Nodal Supply and Demand Situation

The current supply in terms of base demand in cubic metres per hour (CMH) and the analysis of actual demands for each of the nodes in the distribution network is as shown in Figure 4. The graph clearly shows that the current supply at the nodal points fall short of the demands during the peak hours. The water demand during the peak hours is 1.5 times of the nodal supply, i.e. it falls short by 50%,while the supply during the non-peak hours is 2.5 times the demand. Thus this excess water could be stored in a sump, which can be further used to meet the water demand during the peak hours. To address this problem pumps should be installed in all the premises to supply water to the overhead tanks.The major variation in demand takes place at the nodes which lies in front of the University building and the Tech Park. This is due to the large population in these 15 storey buildings.

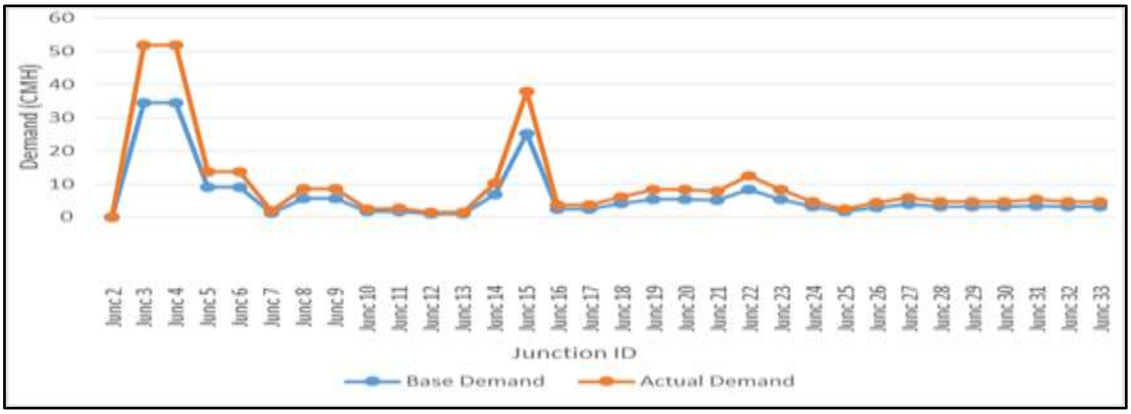

Figure 4: Nodal Supply vs Demand

3.4 Nodal Pressure Result under Current Demand

The results obtained for the pressure head at the nodes are shown in Figures 5 and 6. In SRM campus, many buildings are multi storeyed buildings having heightsof 15-30 m. A minimum pressure head of 12 m is a must for the smooth and effective supply of water. Figure 6 shows that almost all the nodes have pressure greater than 12 m except for the nodes 12, 13 and 14. This is due to the presence of dead ends. Looping the network is the only effective method to overcome this constraint [8].

Figure 5: Pressure variation shown in EPANET

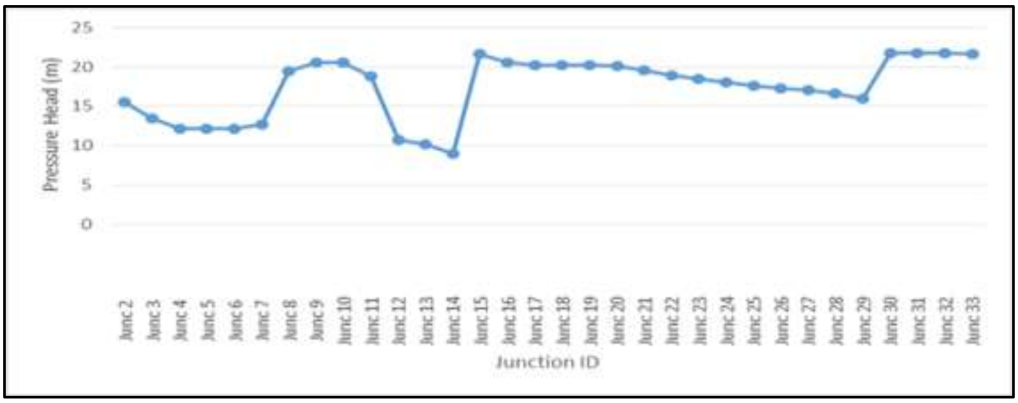

Figure 6: Pressure Head for various junctions

3.5 Output Flow Rate under Current Demand

The flow rates in the network are shown in Figures 7 and 8. The flows in the network are consistent with 23 out of 29 pipes having flow rate above 120 CMH. The pipes having lesser flow rate aresituated near the dead ends.

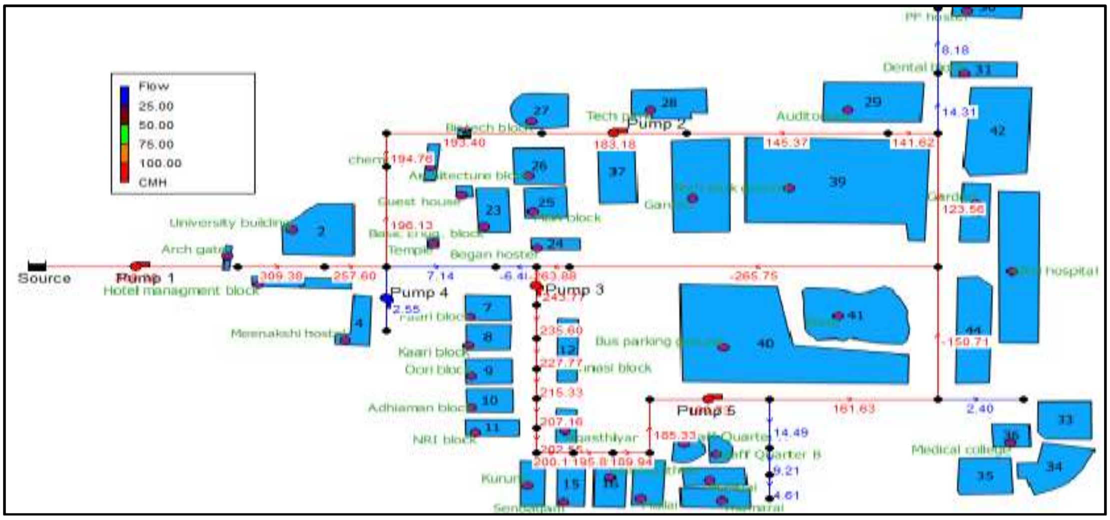

Figure 7: Flow through links shown in EPANET

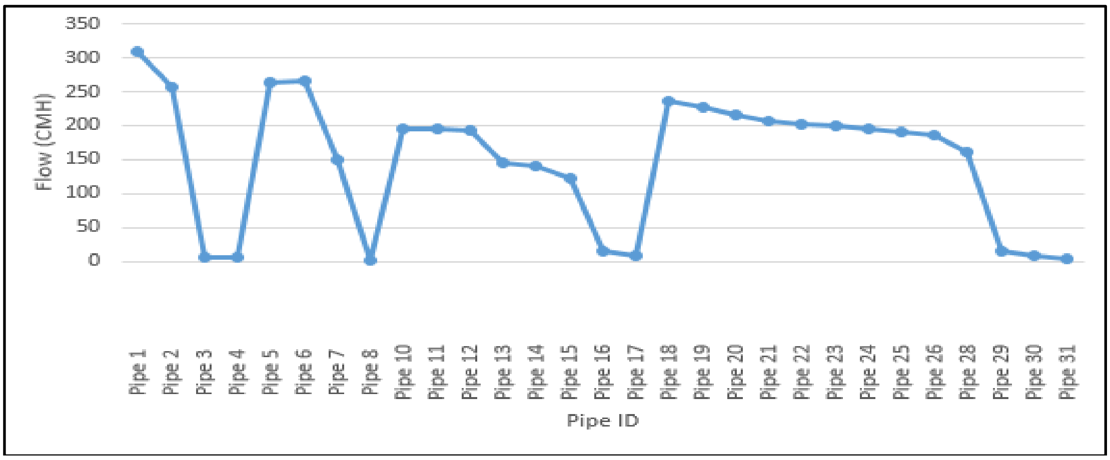

Figure 8: Flow in various links

3.6 Output Velocity in the Network

The velocities are shown in Figures 9 and 10. The velocities range from 0.03 m/s to 1.75 m/s. The minimum and maximum velocity in the network should be 0.6 m/s and 2.3m/s, respectively. The velocity of flow in thenetwork is sufficient except in pipes 3,4,8,16,17,29,30 and 31. The velocity is less in these pipes due to the dead ends.Looping the network is only the proper remedy to overcome this drop in velocity near the dead ends [8].

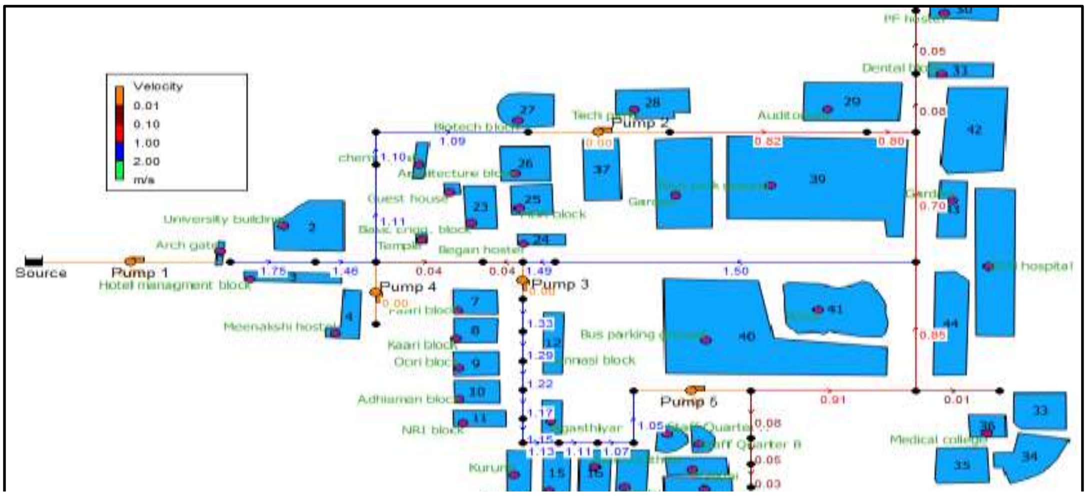

Figure 9: Velocity in pipes shown in EPANET

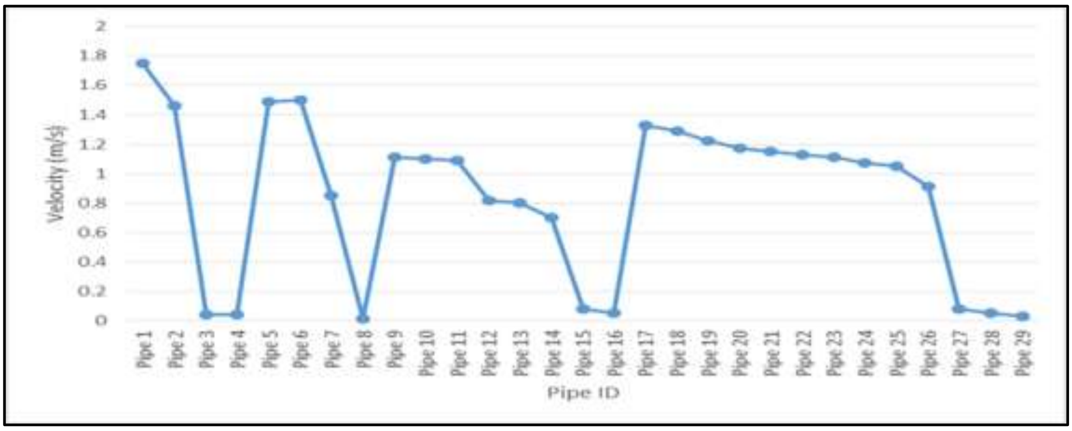

Figure 10: Velocity in various pipes

4. CONCLUSION

The main focus of this study was to analyse the water distribution network in the SRM University campus and identify deficiencies (if any) in its analysis, implementation and usage. It was found that the resulting pressures at all the junctions are found to be greater than 12 m and the flows with their velocities at all pipes are in the range of 0.6–2.5 m/s, which is adequate enough to provide water to the entire study area. One of the major problems is the presence of dead ends within the distribution system. Although this constraint can be removed by looping the pipes in the network, the site conditions are not conducive for looping. All the hydraulic constraints of the distribution system have been overcome to a maximum extent. The minimum pressure head and water demand even during the peak hour is ensured for the supply of required quantity of water. The results verify that the pressures at all the junctions and the flows with their velocities in all the pipes are feasible to provide adequate water to the entire study area.During peak hour, 6–9am and 6– 9pm, the demand of water is more hence the maximum supply is given for 6 hours a day. The water demand during the peak hours is 310 m^3/hr, while the demand during the non- peak hours is 83 m^3/hr. Thus the overall water demand considering all the nodes for a day is 3354 m^3, whereas the supplied quantity of water is about 4950 m^3. Hence there is no overall shortage of water throughout the day.

5. ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness to the SRM University for the cooperation and permission to accomplish the desired study work. The author expresses his sincere thanks and gratitude to Dr. K. S. Satyanarayanan, Professor and Head, Department of Civil Engineering for his valuable suggestions and support in carrying out this work successfully.Finally, the author expresses his hearty thanks to Family and Friends for their kind help and constant encouragement during the course of this work.

6. REFERENCES

[1] Saminu, A., Abubakar, Nasiru and Sagir, L. (2013), “Design of NDA Water Distribution Network Using EPANET” International Journal of Emerging Science and Engineering, Vol. 1, Issue 9, pp. 1-2.

[2] Arjun Kumar, Kankesh Kumar, BharanidharanB,**“**Design of Water Distribution System using EPANET”, International Journal of Advanced Research (2015), Volume 3, Issue 9, Sep 2015, pp. 789 – 801

[3] US Environmental Protection Agency. (2008), Distribution System Research,http://www.epa.gov/NRMRL/wswrd/dw/dsr.html

[4] Rossman, LA. (2000), EPANET 2 Users Manual, http://www.epa.gov/nrmrl/wsrd/dw/epanet/EN2manual.PDF

[5] IS:1172 (1993), Code of Basic Requirements for Water Supply, Drainage and Sanitation, pp.2.

[6] Rossman, LA. (1993). EPANET, Users Manual, Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio

[7] Richard Ainsworth (2004), Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems, pp.39-40.

[8] Adeniran, AE. andOye-lowo, MA. (2013), “An EPANET Analysis of Water Distribution Network of the University of Lagos, Nigeria”, Journal of Engineering Research, 18(2), pp.69-84.